

An Evaluation of the Carbon Sequestration Potential of the Cambro-Ordovician Strata of the Illinois and Michigan Basins

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Kentucky Consortium for Carbon Storage

Seismic Reservoir 2020

Acknowledgements

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Budget

- Total budget of over 6 million dollars
- Including
 - \$4,949,999 from US Department of Energy
 - \$250,000 from Illinois DCEO
 - \$152,000 in-kind from ConocoPhillips
 - \$140,000 from Western Kentucky Carbon Storage Foundation
 - \$70,000 from Seismic Reservoir 2020
 - Additional cost share from state surveys and universities

Objective

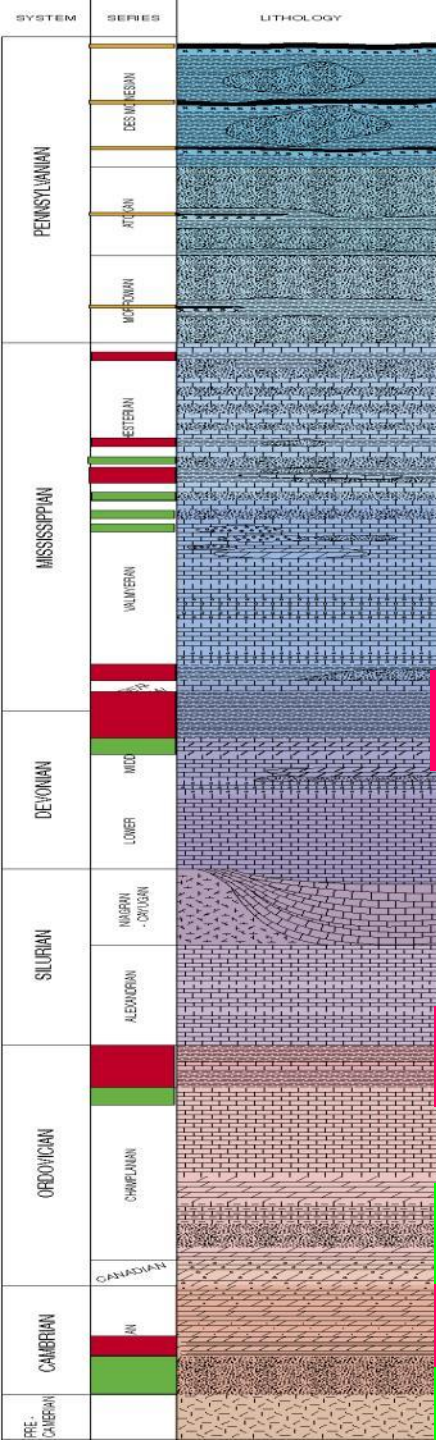
- Characterize new areas for sequestration in southern Illinois, southern Indiana, western Kentucky, and Michigan,
particularly where the Mount Simon Sandstone is not a viable injection target.

Why do the study?

- Mt. Simon has limited sequestration potential in southern Illinois and western Kentucky
- Limited field experiments or detailed studies have been conducted on the potential of the carbonate Knox Supergroup, St. Peter Sandstone, and the Maquoketa Shale.

What are our sequestration targets?

Illinois Basin Stratigraphic Column Showing Seals and Sinks



New Albany (Seal)

Mt. Simon is overlain by 3 thick impermeable shales and numerous thinner shale-rich strata

Maquoketa (Seal)

St Peter (Sink)

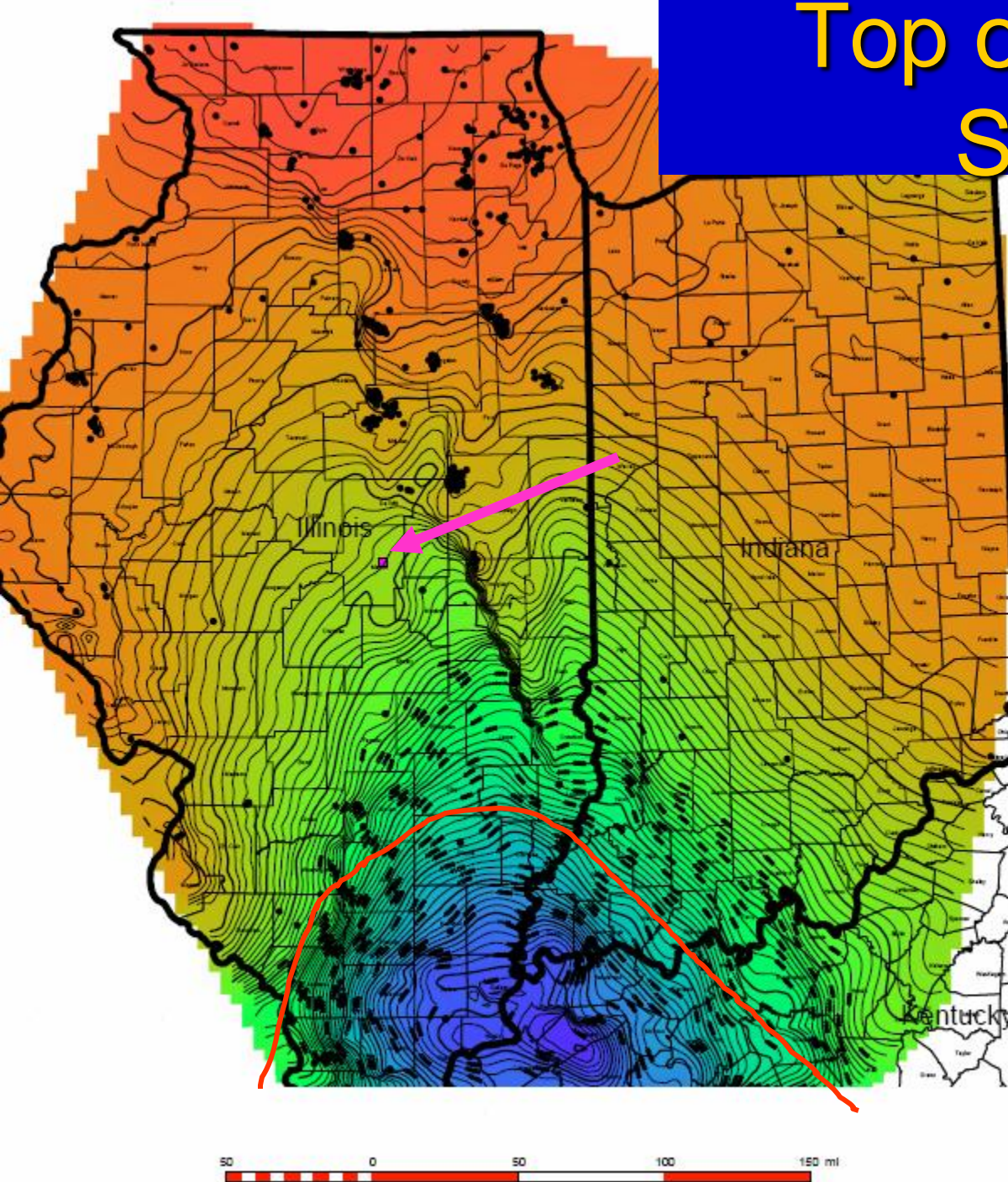
Knox (Sink)

Eau Claire (Seal)

Mt. Simon (Sink)



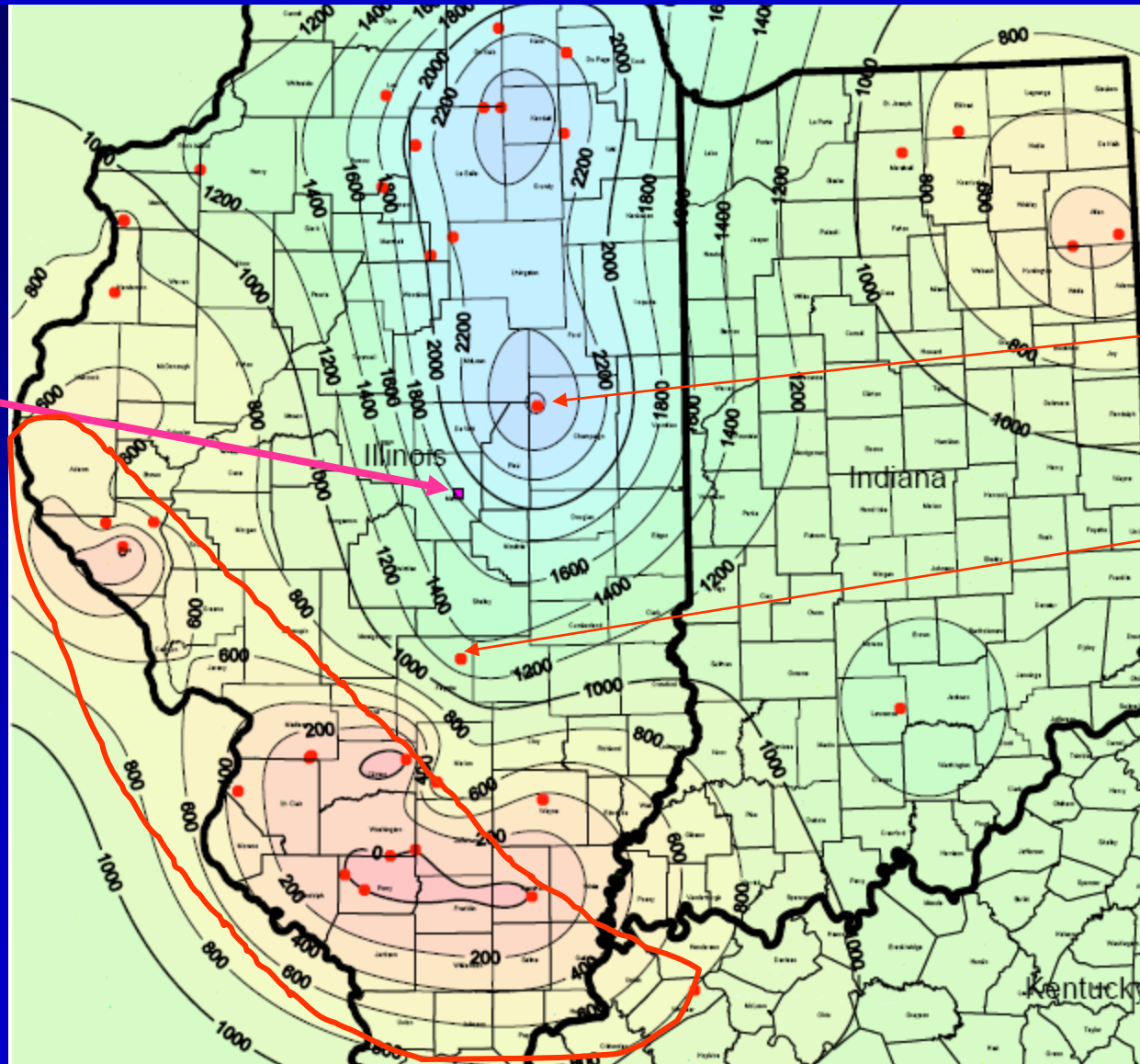
Top of Mt. Simon Structure



At Decatur the top of the Mt. Simon is 5571 measured depth

South of red outline the Mt. Simon may be too deep

Thickness of the Mt. Simon Sandstone

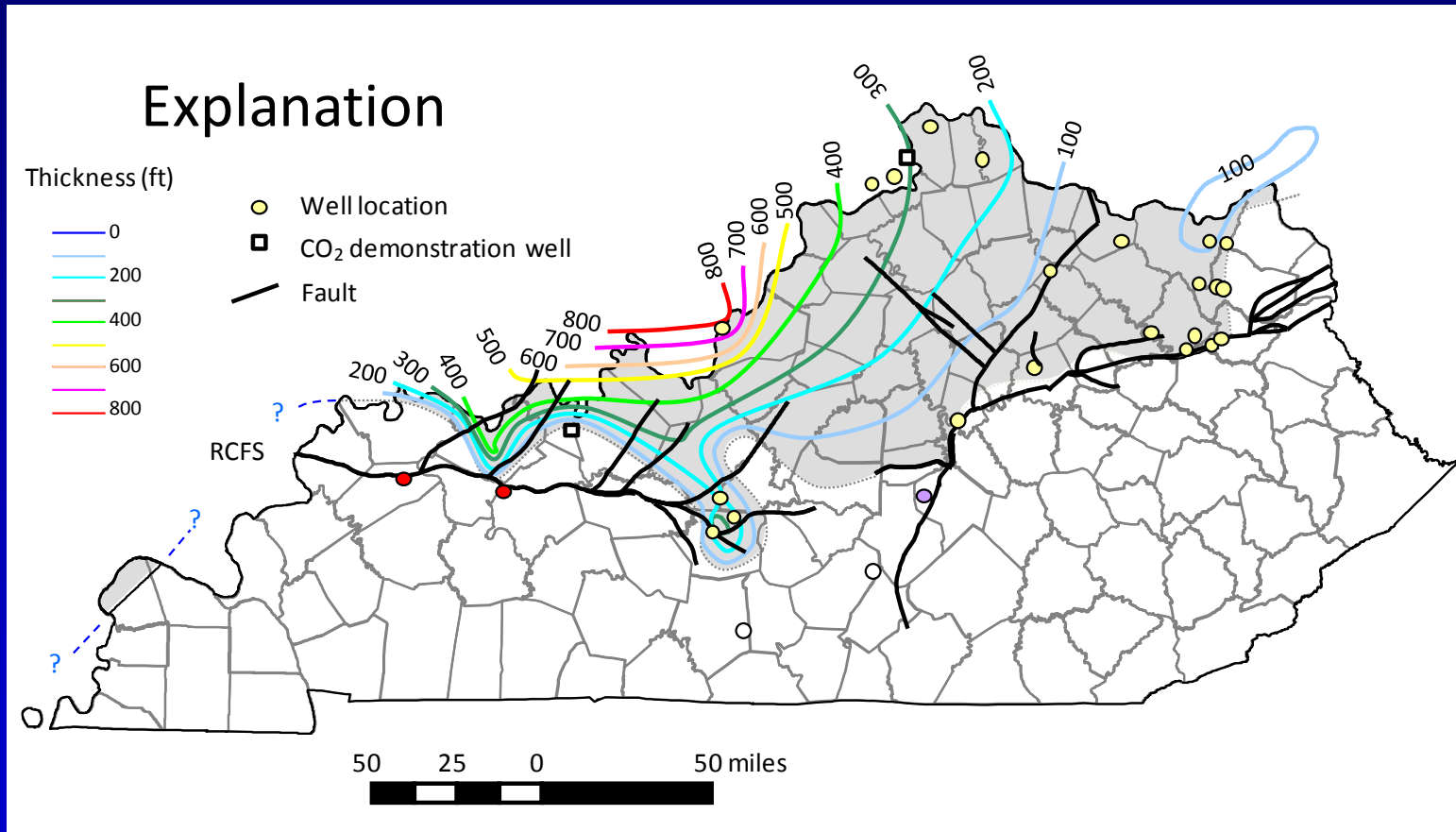


Hinton #7
penetrated 2600
feet of Mt. Simon

Wells with
Precambrian
granite

Mt. Simon may be
too thin within the
red outline

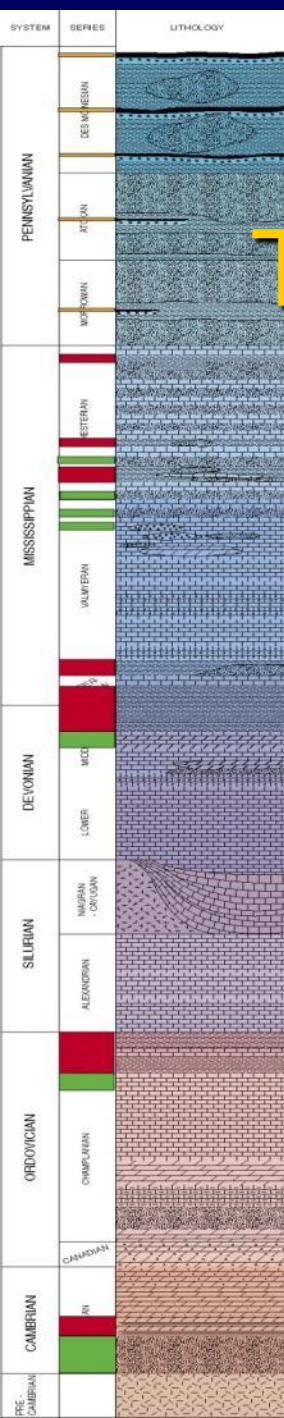
Mount Simon Thickness, Kentucky



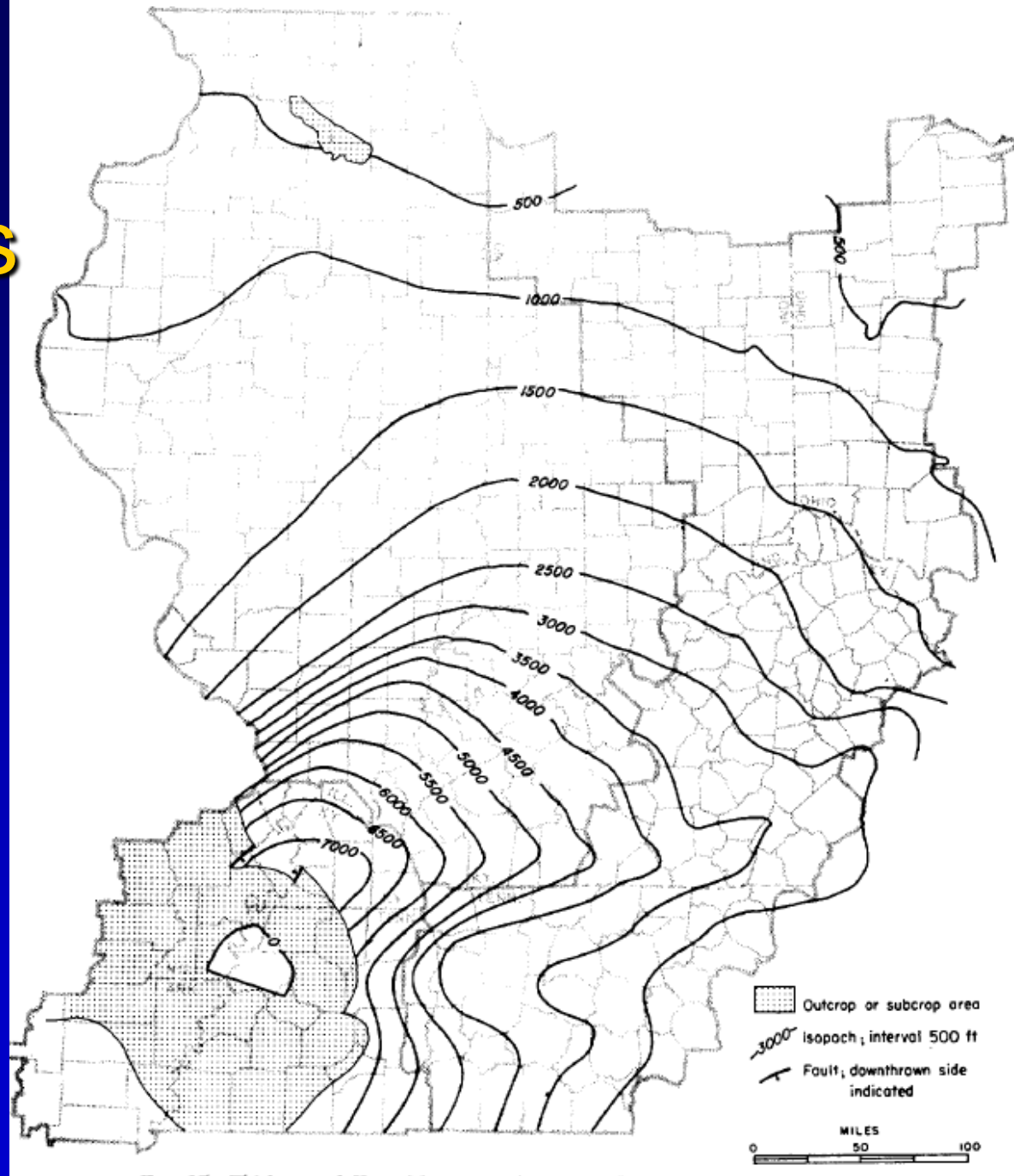
Why the Knox and St. Peter?

- Knox is regionally widespread at supercritical CO₂ depths, yet shallower than the Mount Simon
- Evidence for significant porosity in the Knox, although in thinner, more complex reservoir units
- St. Peter Sandstone has significant thickness and porosity in the Michigan Basin; but has not been characterized in detail by partnerships

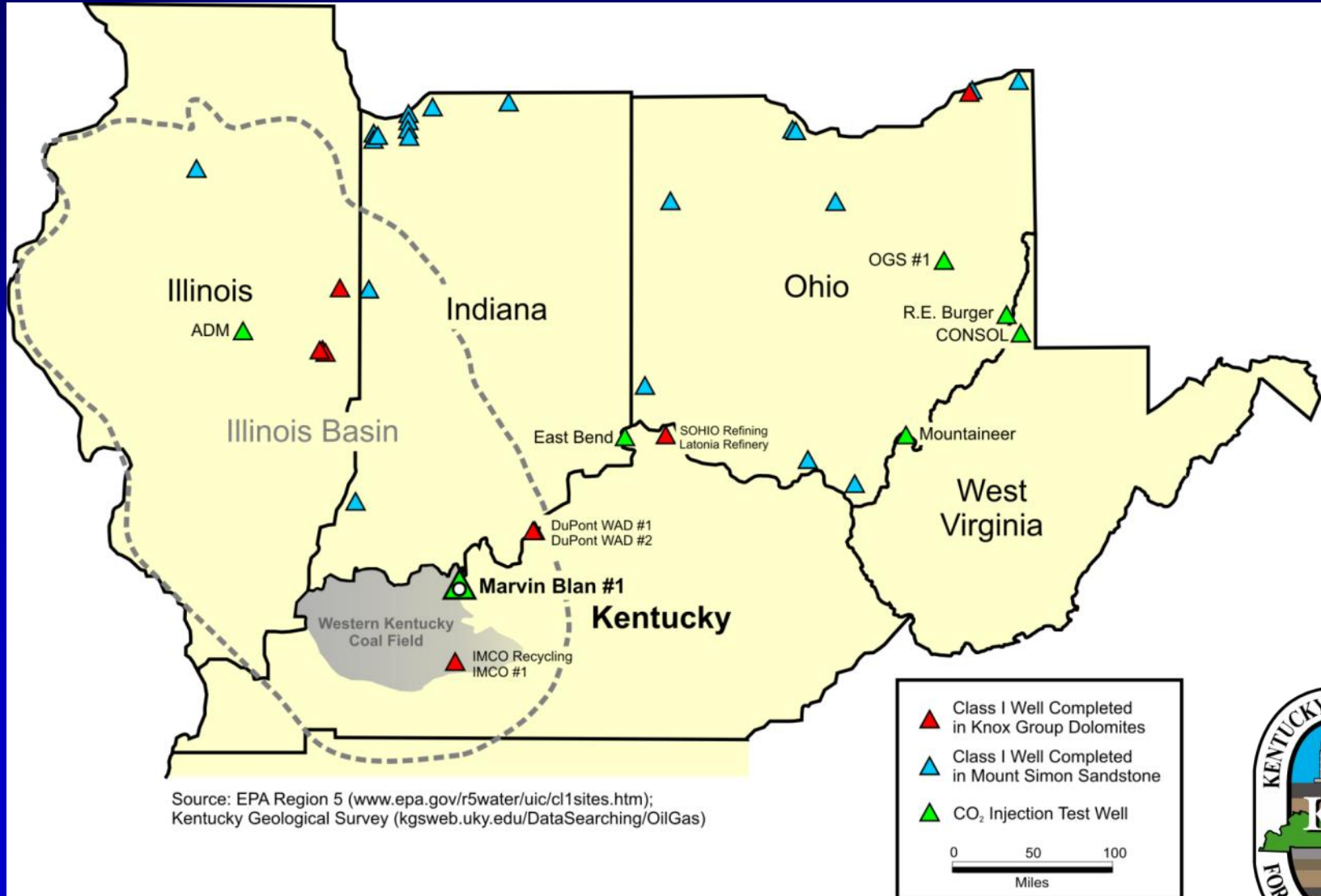
Knox Thickness



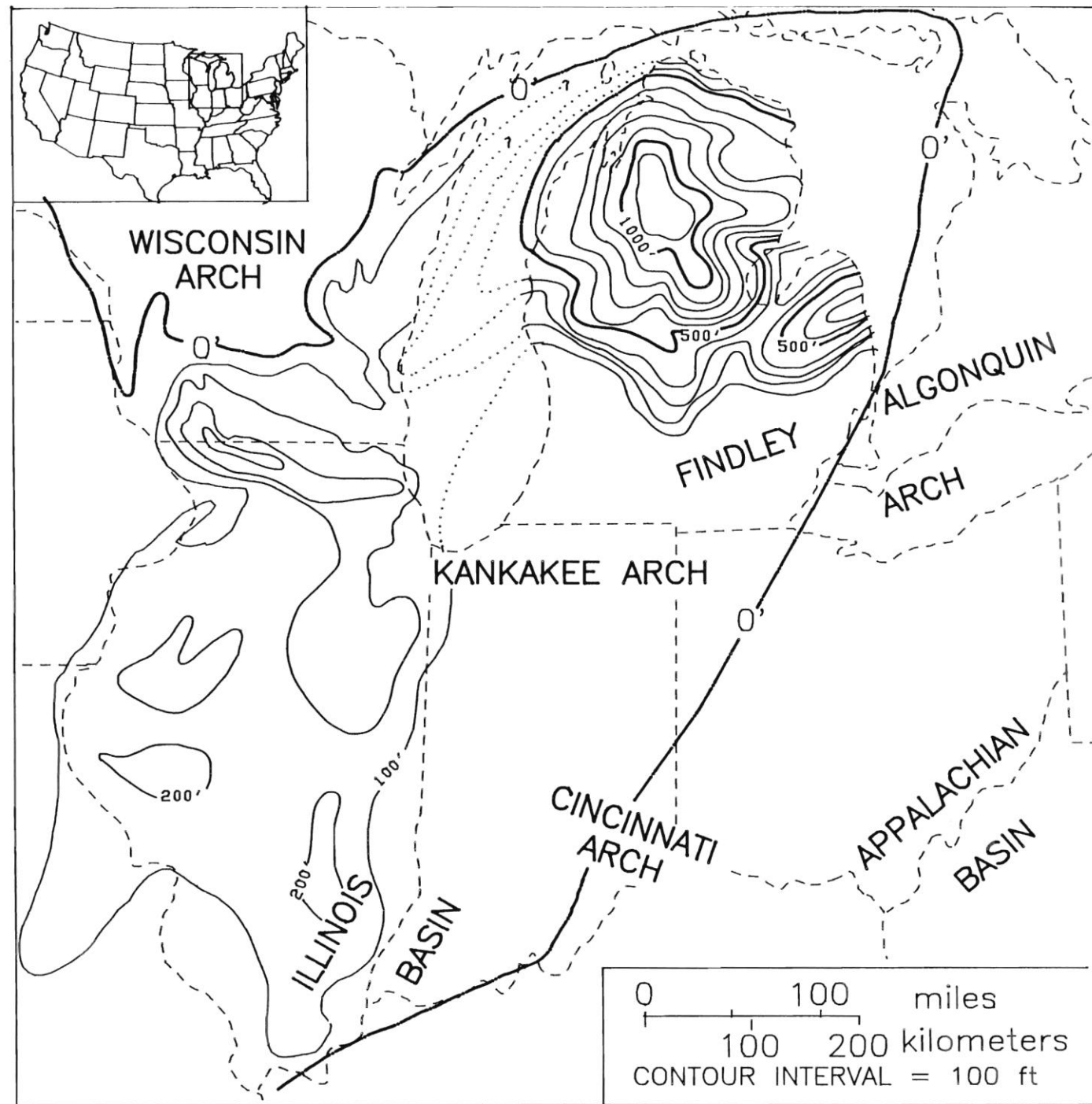
Knox



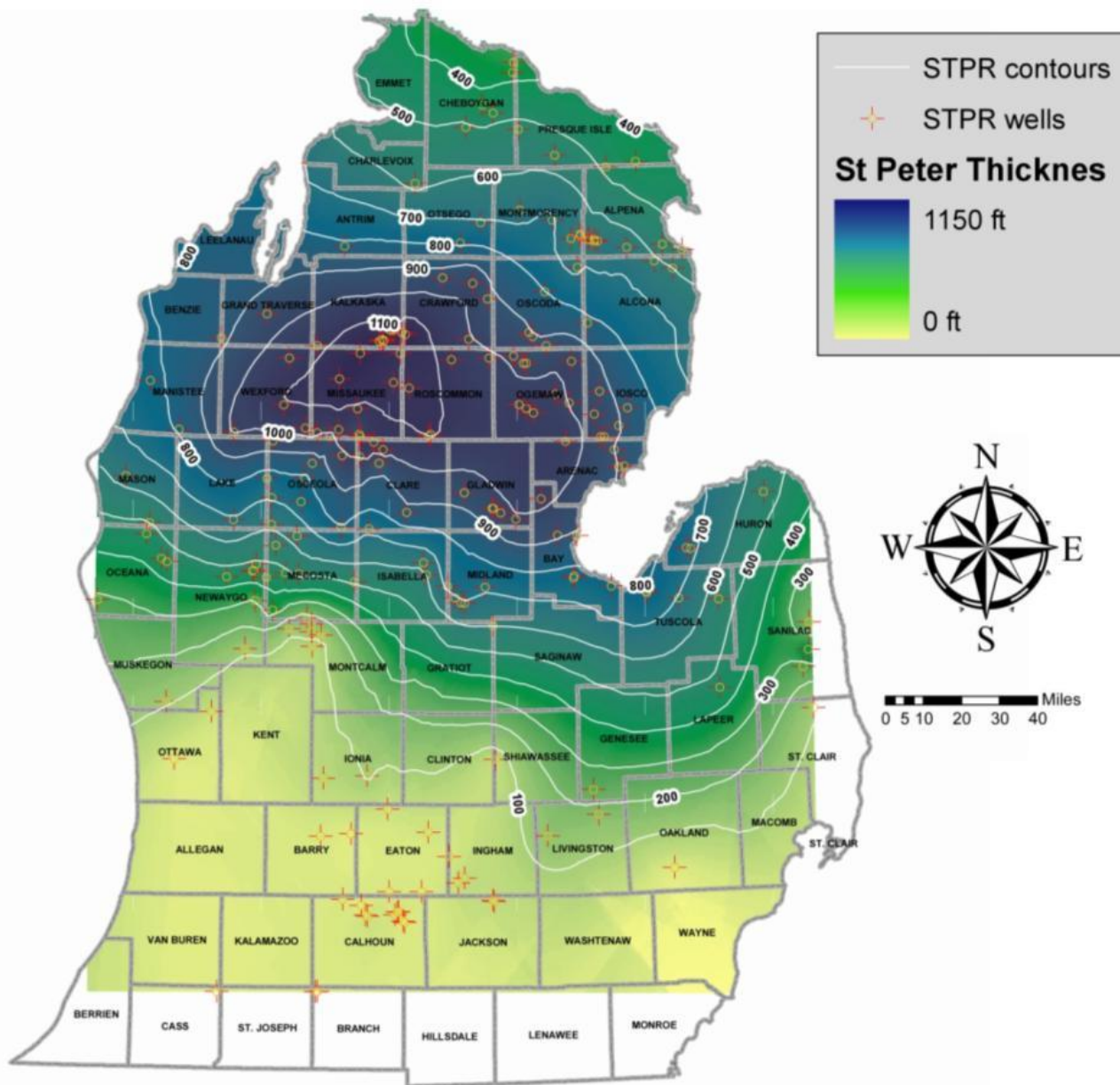
Waste Injection Wells In Ky Use the Knox

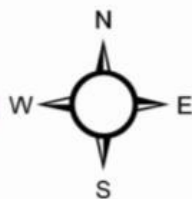
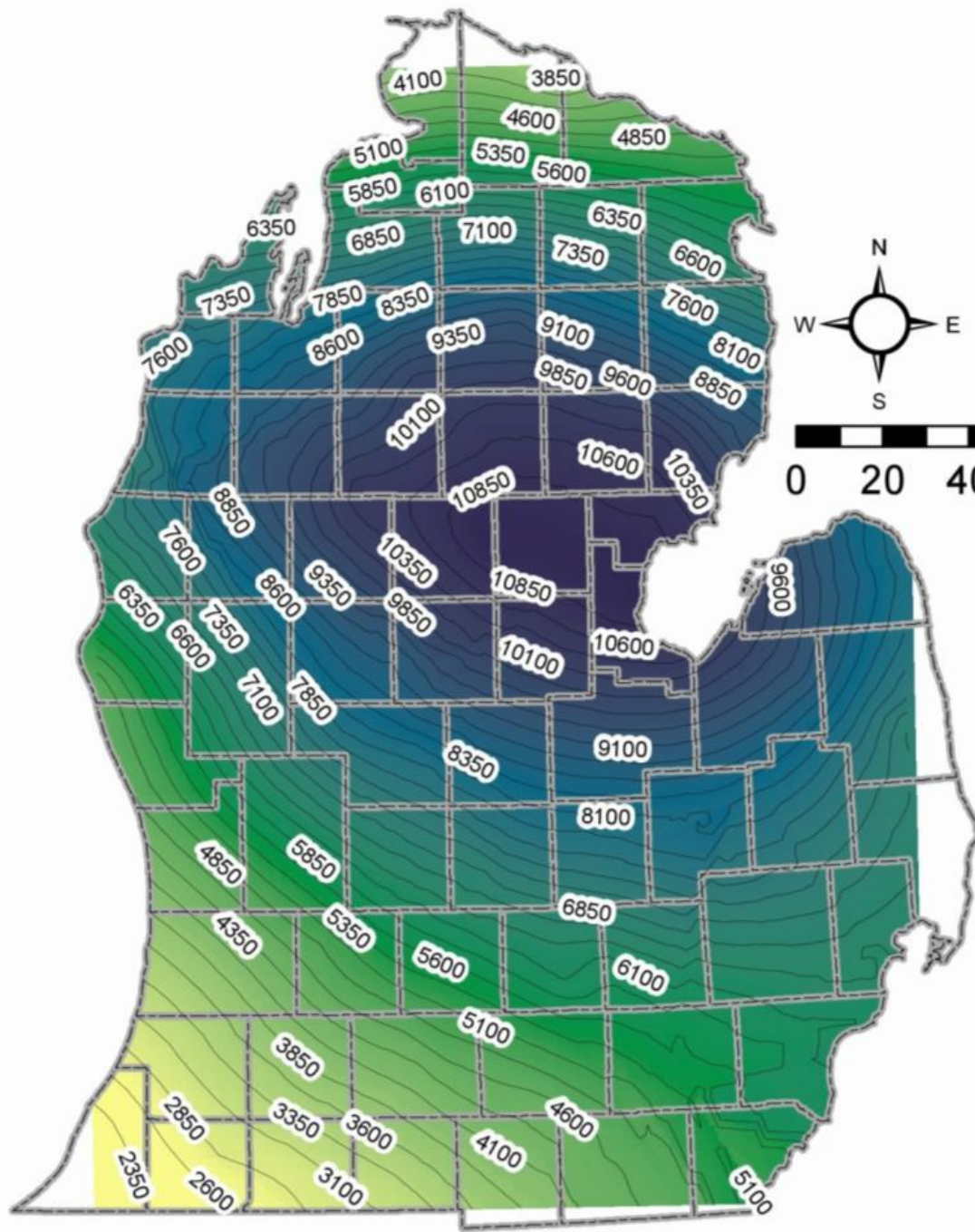


Regional St. Peter Sandstone Thickness



St Peter Sandstone Thickness

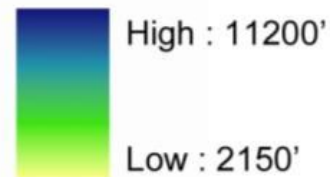




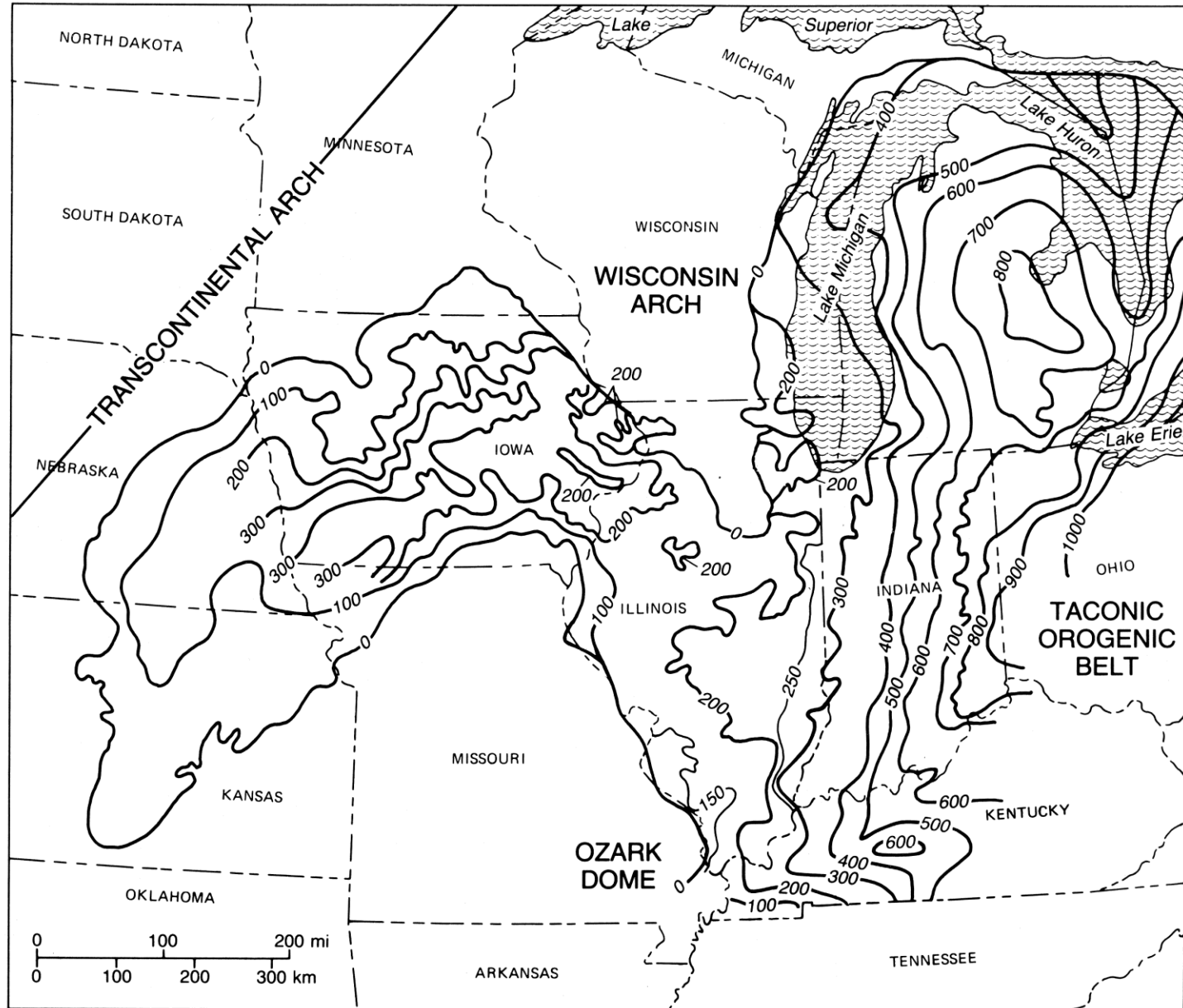
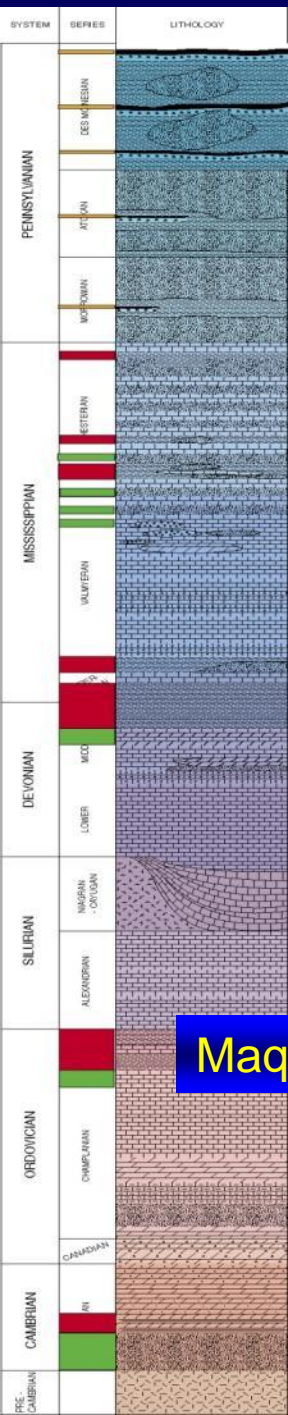
0 20 40 80 Miles

St. Peter Sandstone Overburden Thickness

Thickness in ft



Thickness of Maquoketa



Project Implementation

■ Knox Supergroup

- New core and log data, Decatur, Illinois
- New injection testing, and 3D VSP acquisition, existing well in Hancock County, Ky.
- Seismic interpretation, geochemical modeling, flow modeling, seal analysis, core interpretation with new and existing data

■ St. Peter Sandstone

- Interpretation of existing data (no new data acquired)

Year 1 Tasks

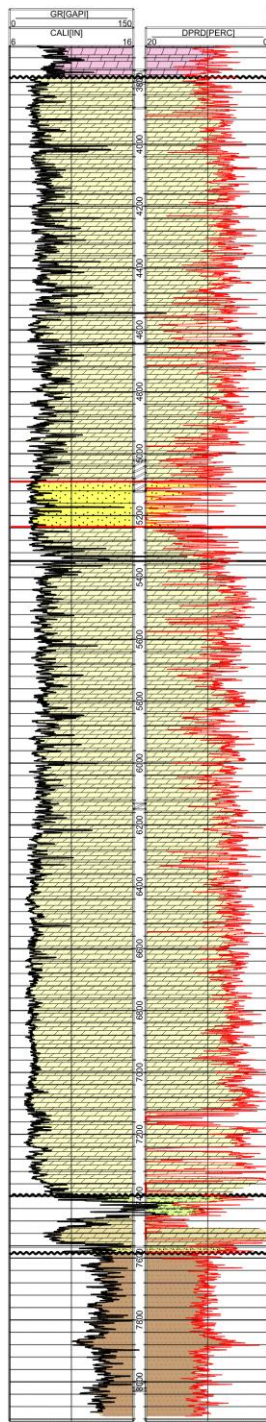
- Compilation of regional database
- Acquire whole core of Knox and Maquoketa from the Phase III monitoring well at Decatur in Illinois
 - 60 ft Maquoketa Shale (seal)
 - 2– 30 ft cores in the Knox (seal and reservoir)
- 2nd phase of CO₂ injection tests into the Knox in the KYCCS Hancock Co., Ky. well
- 3D VSP in Hancock County well

Year 1 Tasks (cont.)

- Regional characterization of Knox and St. Peter Sandstone stratigraphy, structure, thickness, and reservoir quality

Western Kentucky Project Area





St. Peter Sandstone (6" thick)

Upper Knox dolostones

Gunter Sandstone

**Deep stratigraphic units,
KGS #1 Blan well,
Hancock Co.**

Lower Knox dolostones

Eau Claire Fm. (**Mt. Simon Sandstone absent**)

Precambrian Middle Run Formation (red sandstone/siltstone)



Blan Well Summary

- Open-hole completion from Knox down
- Over 23,000 bbl water injected into the Knox; 323 tons of CO₂ injected at high rate
- Dual porosity system indicated
- Data set includes 2D seismic, zero-offset VSP, complete logs w/ FMI, fm brine samples, 395 ft core, PLT logs, temperature decay logs

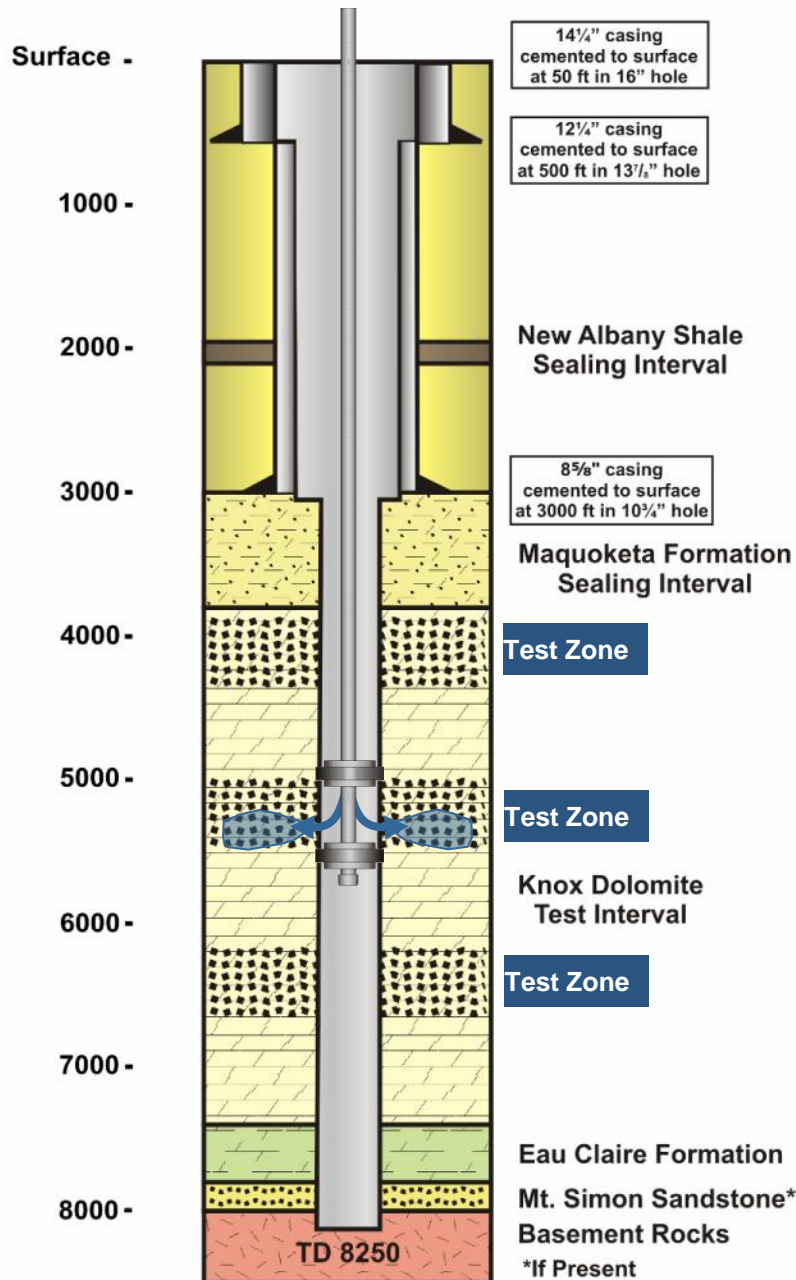


KGS #1 Blan Research Well



Photo: Brandon Nuttall

Testing Program





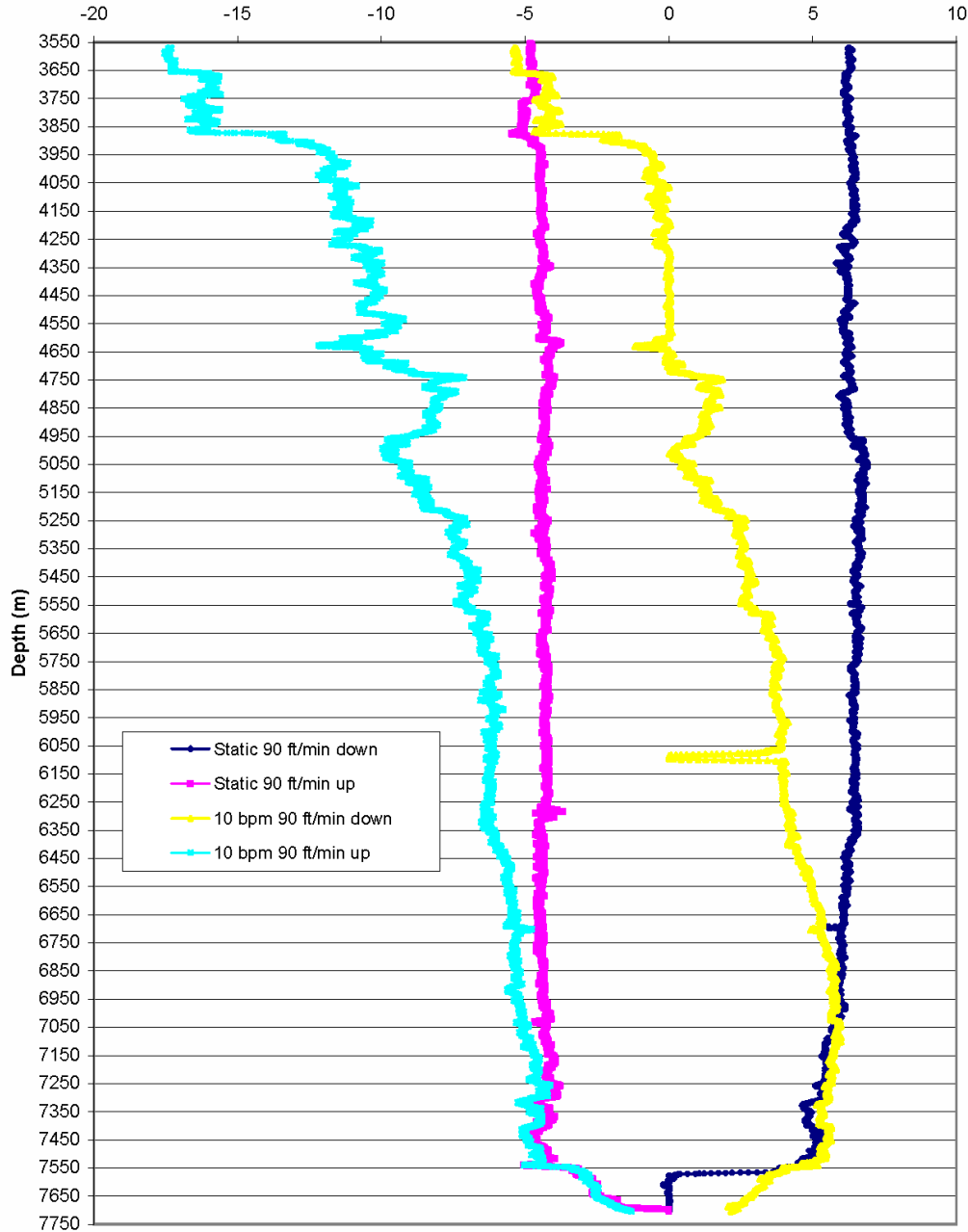
Plan B

- Set a single packer, test thick open-hole intervals
 - 6,089–7,460: 1,371 ft zone: 7,200 bwpd, 1510 psi buildup
 - 3,620–7,460: 3,840 ft zone: 14,450 bwpd, 250 psi buildup
- Good data from these tests
- Techniques used to ID permeable zones
 - Spinner, pressure and temperature decay logs



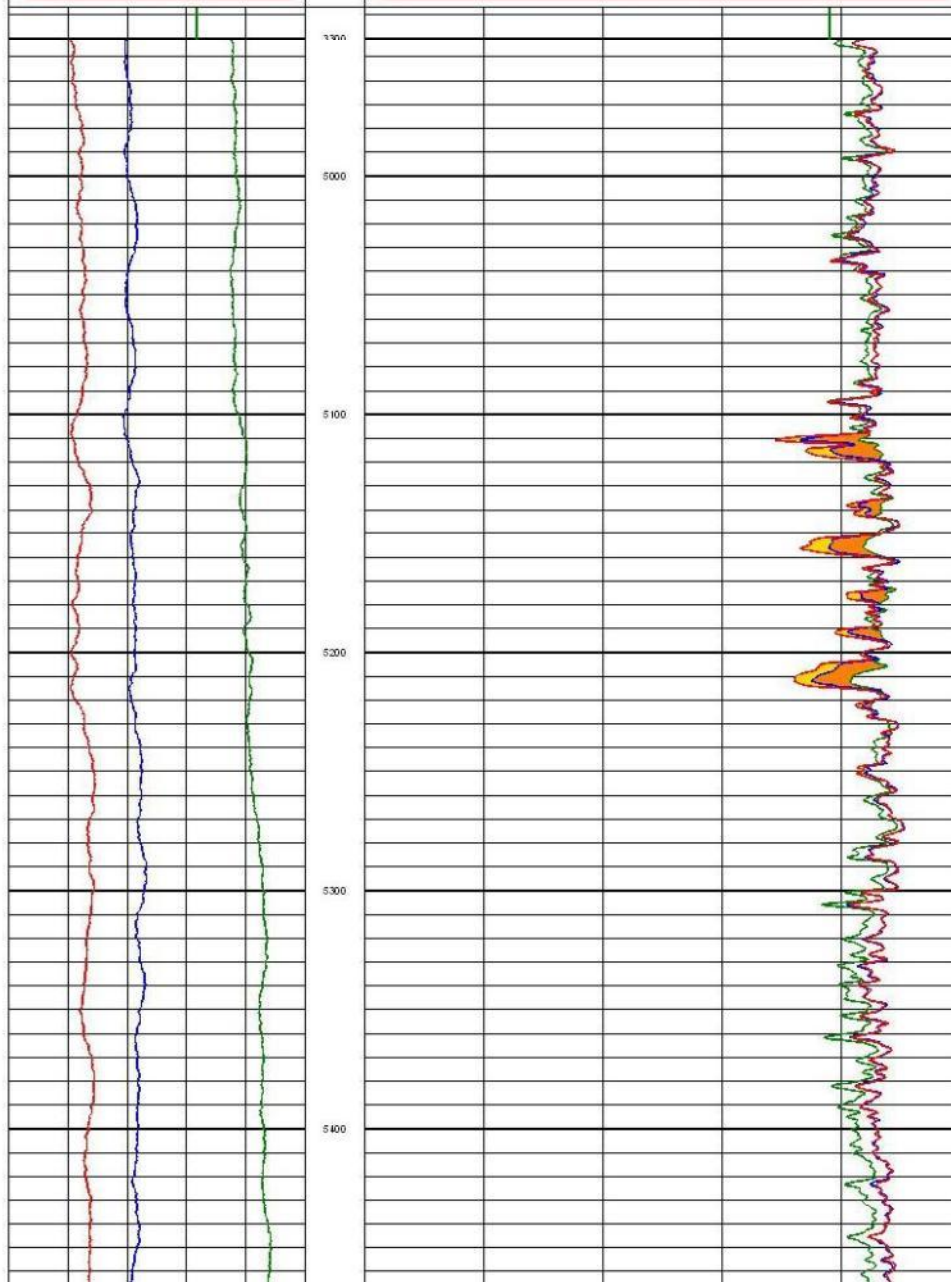
KGS Marvin Blain #1
90 ft/min Spinner Survey Passes
August 10, 2009

Spinner Revolutions per Second (RPS)



Spinner Survey Data During Brine Injection





Boron Solution Used as a Tracer

3,175 bbl. of boron (borax) solution injected, traced with pulsed neutron logging during/after injection



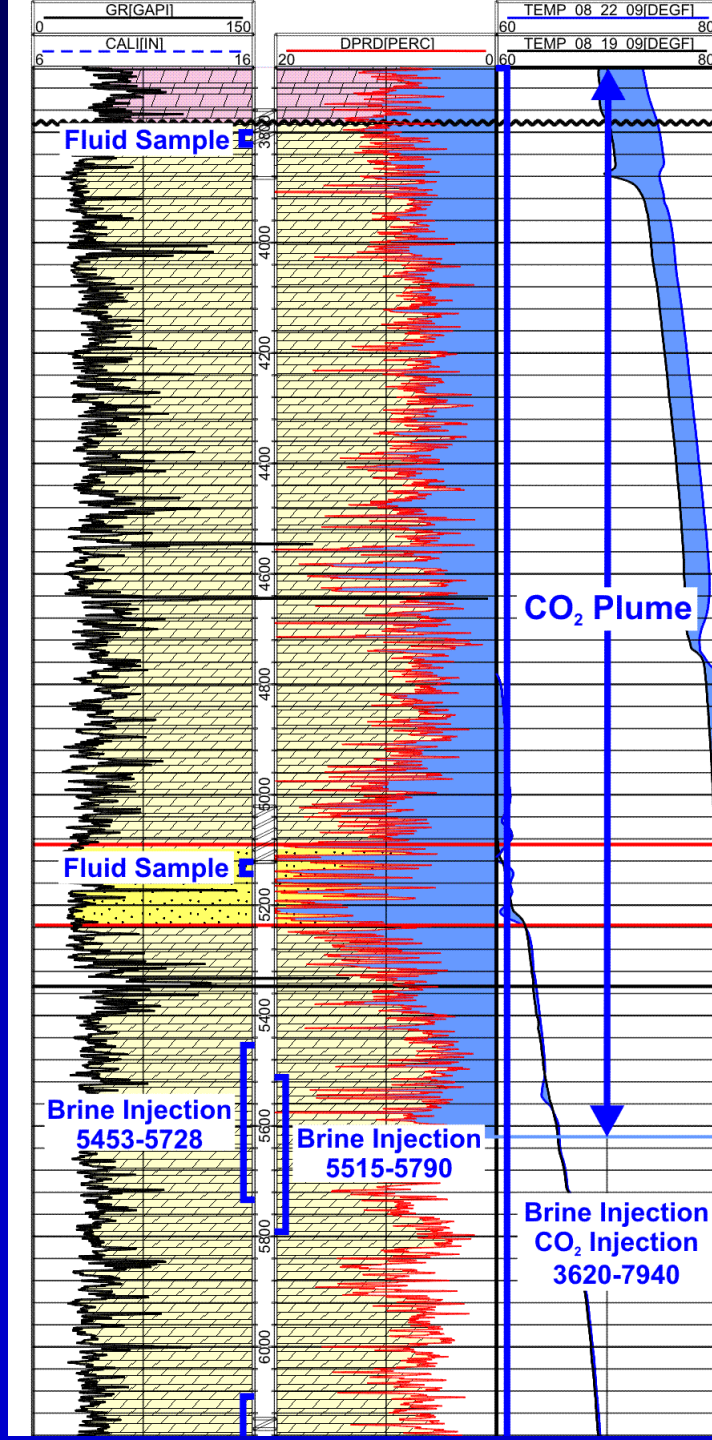
7 lb/bbl borax
decahydrate



Blan CO₂ Injection

- CO₂ injected into entire open hole interval w/ packer set in casing @ 3,603'
- 1,765 bbl CO₂ (323 tons) injected at a constant rate of 4 bpm
- Final injection BHP=1754 psi and BHT=103°
- Temperature logs run before and after CO₂ injection to attempt to identify zones





Pre- and post-CO₂ injection temperature logs indicate CO₂ entered over upper 2,000 ft interval

Year 2 Tasks

- Regional capacity estimates and injectivity of the 2 formations
 - CO₂ injectivity of the St. Peter derived from gas storage data
 - Numerical flow simulation for Knox & St. Peter
- Diagenetic studies on Knox cores from Hancock County and Decatur
- Seal analysis, geomechanical studies, Maquoketa cores, Il. and Ky.

Year 2 Tasks (cont.)

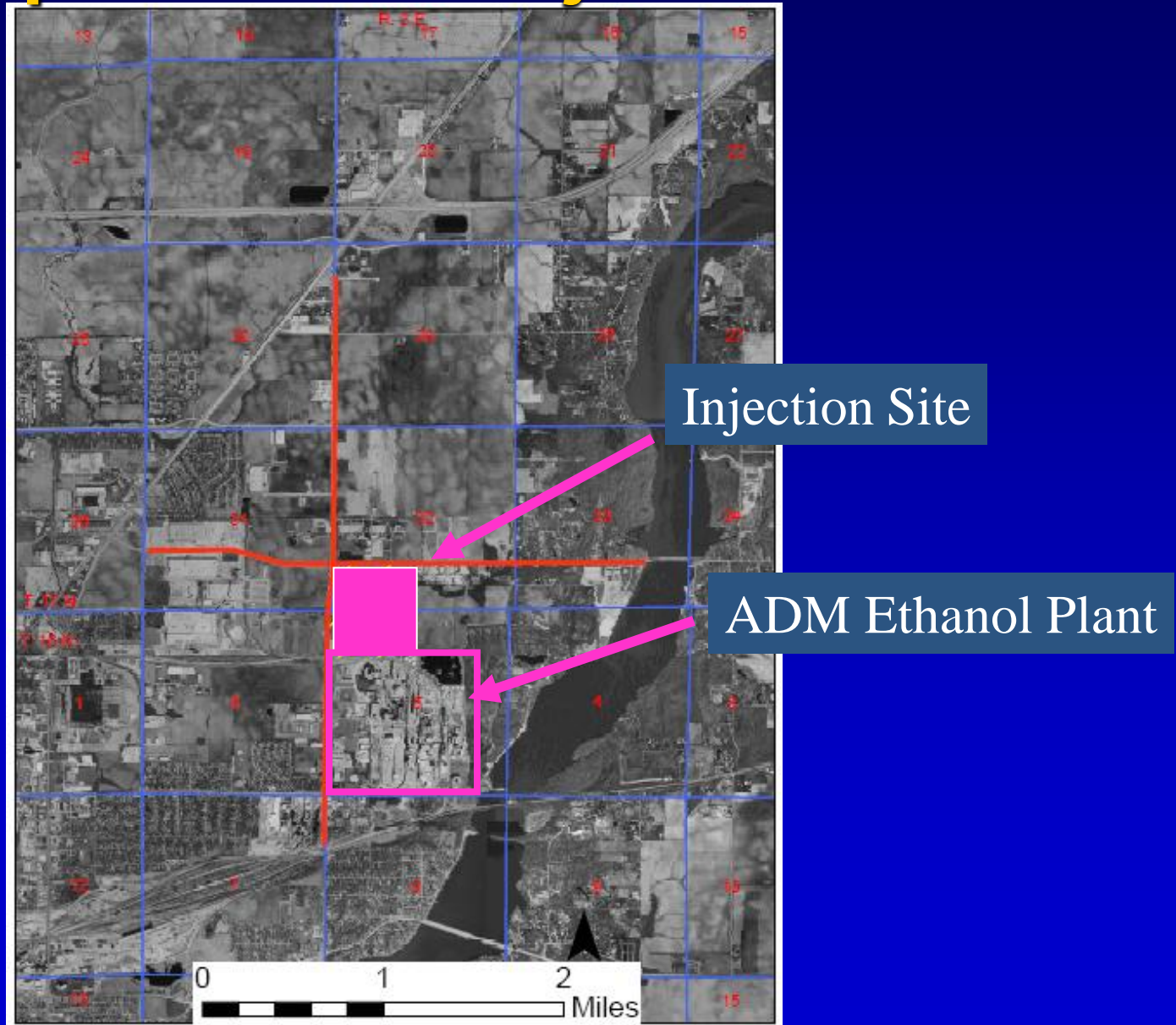
- CO₂ reactions with brine and rock
 - Modeling using brine chemistry and core data from Hancock Co. and Decatur
- Seismic inversion modeling using 2D datasets in Kentucky and 3D dataset from Decatur to improve porosity prediction

Knox Dolomite Cores

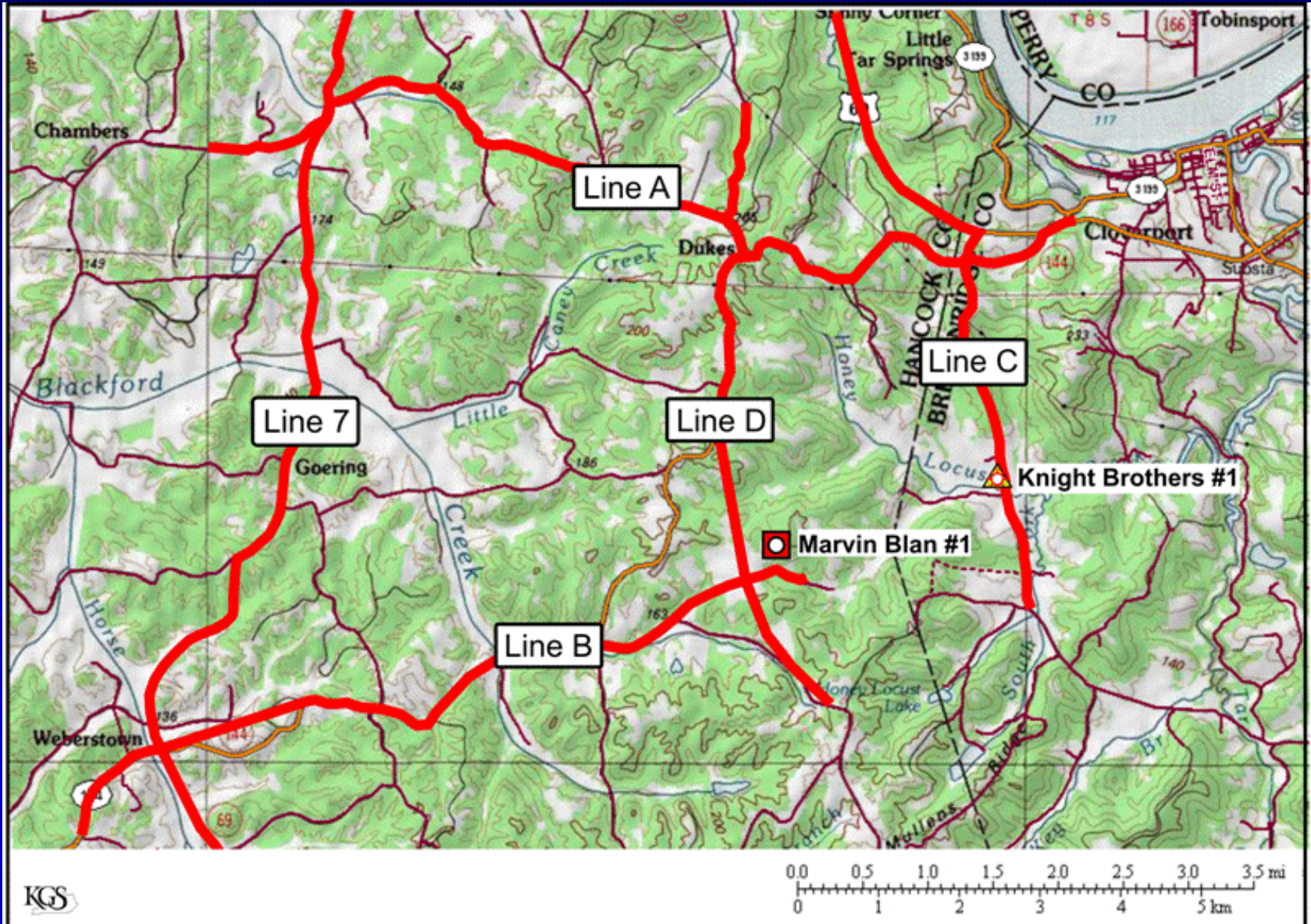
- Knox Dolomite was cored in three intervals (total 243 ft) to test reservoir properties
 - “St Peter”-Beekmantown (123 ft)
 - Beekmantown-Gunter (101 ft)
 - Copper Ridge (19 ft)
 - Found porosity system to be a complex of preserved fabric, primary dolomite porosity, vugs, and fractures
- Extensive analysis program
 - Routine core analysis
 - Mechanical properties
 - XRD mineralogy
 - CO₂ core flood
 - Threshold entry pressure



Seismic Reflection Across the Proposed ADM Injection Site



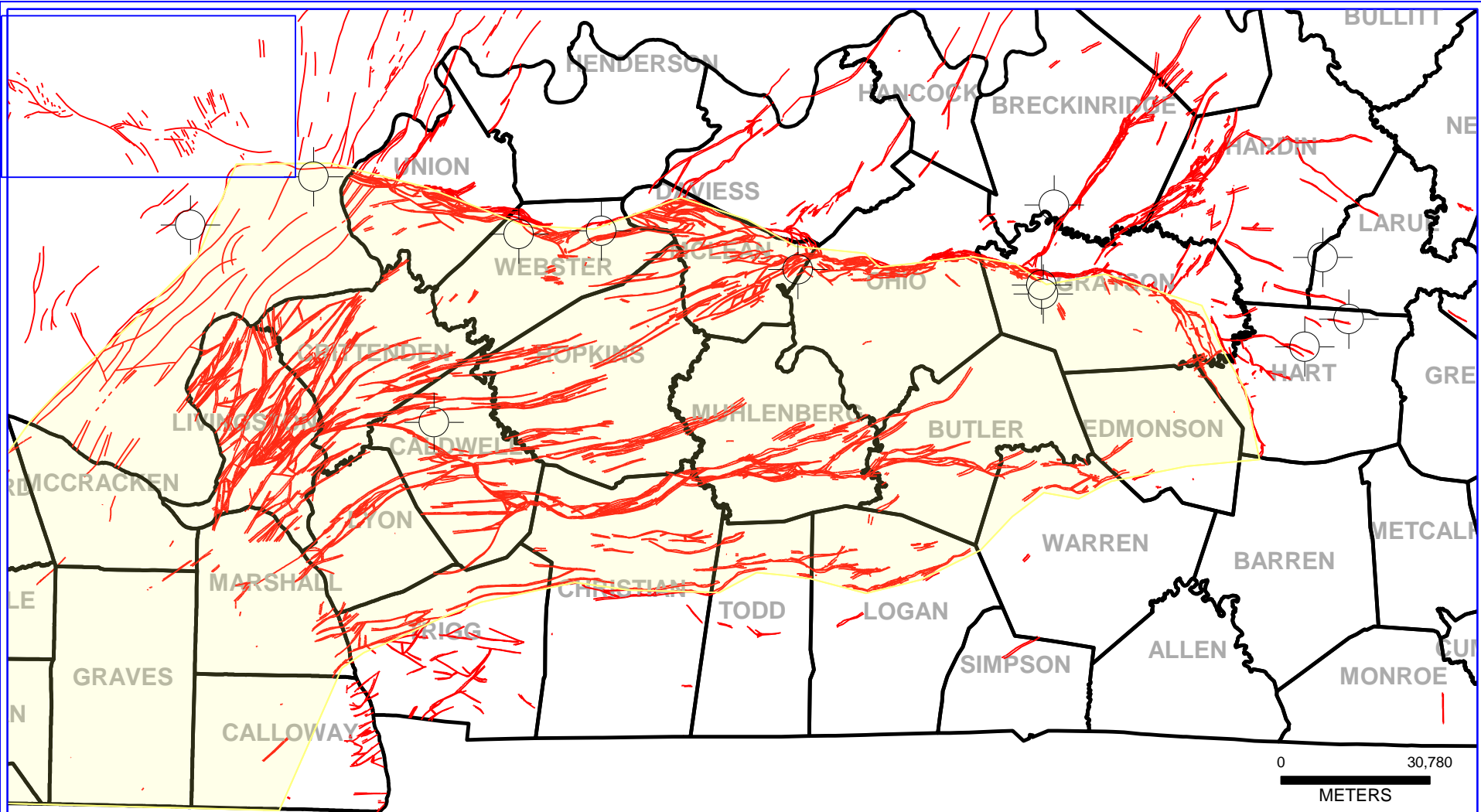
24 miles 2D seismic acquired by WesternGeco in Hancock County, Ky. area



Year 3 Tasks

- Leakage pathway characterization
 - Knox fracture analysis
 - Fault seal risk assessment, western Ky.
- Complete a best practice manual
- Create GIS layers of high and low potential areas
- Site risk assessment

Faulting in Western Kentucky: Friend or Foe?



Ultimate Goal

- Define fairways where the Knox and the St. Peter reservoirs would be good sequestration targets